DOCUMENT RESUME

ED 072 529 24 EA 004 845

AUTHOR	Follettie, Joseph F.
TITLE	Alternative Designs for Educational Systems.
INSTITUTION	Southwest Regional Educational Lab., Inglewood, Calif.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Lab. Branch.
REPORT NO	SWRL-TR-45
BUREAU NO	BR-6-2865
PUB DATE	14 Dec 72
CONTRACT	OEC-4-7-062865-3073
NOTE	48p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Decision Making; *Design; Educational Finance; *Educational Research; Individualized Instruction; *Instructional Systems; Management Information Systems; Productivity; *Relevance (Education); *School Systems; Systems Approach; Systems Concepts; Technical Reports
IDENTIFIERS	*Educational Systems

ABSTRACT

Four alternative designs for educational systems are sketched consonant with existing and potential scientific and technical knowledge and are contrasted with the prevailing generic educational system and each other. Systems are compared for relevance and productivity, for information contained in their proficiency tests, and for their capability for individualizing instruction. The set of systems is structured to aid the educational R&D decision process and therefore illustrates a framework for such decisions within a timeframe that extends from the present to a point lying one or two decades in the future. (Author)

SOUTHWEST REGIONAL LABORATORY FOR EDUCATIONAL RESEARCH & DEVELOPMENT

EA 004 845

PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL HAS BEEN GRANTED BY
Southwest Regional Laboratory
TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE U.S. OFFICE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER.

Alternative Designs For Educational Systems

TR 45 14 December 1972

This document has been distributed to a limited audience for a limited purpose. It is not published. Copies may be made only with the written permission of Southwest Regional Laboratory for Educational Research and Development, 4665 Lampson Avenue, Los Alamitos, California 90720.

ED 072523

SOUTHWEST REGIONAL LABORATORY
TECHNICAL REPORT 45
DECEMBER 1972

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
OFFICE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY

ALTERNATIVE DESIGNS FOR EDUCATIONAL SYSTEMS

Joseph F. Follettie

ABSTRACT

Four alternative designs for educational systems are sketched consonant with existing and potential scientific and technical knowledge and are contrasted with the prevailing generic educational system and each other. Systems are compared for relevance and productivity, for information contained in their proficiency tests, and for their capability for individualizing instruction. The set of systems is structured to aid the educational R&D decision process and so illustrates a framework for such decisions within a timeframe that extends from the present to a point lying one or two decades in the future.

CONTENTS

		Page
I	INTRODUCTION	1
II	INSTRUCTIONAL RELEVANCE AND PRODUCTIVITY	5
	Instructional Relevance	5
	Instructional Productivity	8
	Costs of Instruction	9
	Effective Instruction	11
	System Accountability	13
	Individualization of Instruction	13
	Evaluation of Instruction	16
III	PREVAILING AND ALTERNATIVE GENERIC EDUCATIONAL SYSTEMS	17
	The Generic NEG System	17
	ORE System Alternatives to NEG	19
	A First ORE System (DPG)	19
	A Second ORE System (HPG)	22
	What Other ORE Systems Are Required?	24
	A Third ORE System (HPG_2)	27
	A Fourth ORE System (IMI)	28
	Synopsis of ORE Systems	32
IV	CONCLUDING NOTE	37
	TECHNICAL APPENDIX	39
	REFERENCES	45

ALTERNATIVE DESIGNS FOR EDUCATIONAL SYSTEMS

Joseph F. Follettie

I

INTRODUCTION

An institution whose performance lacks potency, pertinence, or productivity may grasp at every offered straw in seeking to improve its performance. Unfortunately, its tendency will be to attempt to correct deficiencies by adopting a random resource-assignment strategy concocted by the misinformed, underinformed, chloroformed, and venal. Use of such a strategy is analogous to playing against an honest roulette wheel. However, when the wheel is of known dishonesty, the long-term player who assigns resources at random cannot expect to do well. Of course the consequences of using a random resource-assignment strategy on an individual basis are much less significant than when a societal institution chooses to pursue the strategy; undesirable consequences of grand proportions may threaten when the player is such an institution. Yet our educational institution continues drawn to the strategy. Educational underproductivity has led to a plethora of ingenious and disingenious attempts to improve performance, or at least societal perception of performance, in schools. The real and alleged implications of science and technology, good science fiction, and dime novels alike have found their way into the schools during one season or another over the years. While the per capita return apparently has been advancing with time, the gap between the return that schools achieve and that which society requires apparently is widening. Moreover, cost-return apparently is declining.

While the ultimate concern of this paper is the state of prevailing education, its immediate concern is the state of the R&D enterprise that represents society's best hope for elevating performance of the educational institution. The problem is that educational R&D and an associated research community have also tended toward a random resource-assignment strategy. Moreover, among those who are interested in perfecting educational R&D can be discerned a tendency to view the effort to appreciably elevate relevance and productivity of education as a zero-sum game that one genius or coterie of geniuses will win at the expense of all other players. This tendency underestimates the magnitude of the required effort.

If one defines an alternative to the prevailing educational system on a single characteristic--e.g., enrollment agent (the government vs. voucher-backed parents), directiveness (high directivity of the prevailing

school vs. indirectivity of the informal school), or scheduling (fixed vs. flexible schedules)--then the alternatives to the prevailing system approach infinity. Considering the factors that evidence and reason suggest should characterize schools that give the nation the education it is paying for, most single-factor alternatives to prevailing education should prove less than compelling. Although traditional small-scale research has tended to formulate alternatives to the prevailing system on the basis of differences in one or a few factors, it is increasingly recognized that production of definitive findings presupposes that the research stems from an ambitious multivariate experimental design--cf, Scriven (1967), Siegel & Siegel (1967), and Stephens (1967).

An entertainably more powerful approach to formulating single-factor alternatives is formulation of alternative systems. Any such system should subsume all factors that science and technology suggest are pertinent and that development cost bounds in time and dollars permit consideration of. The ultimate such factors are those of relevance and productivity. For if one asks what an educational system should be doing, an acceptable answer in abstract terms is that it should be providing relevant instruction and allied services (e.g., child care in the sense discussed by Bereiter, 1972) on as productive a basis as the pertinent science and technology allow. Neither productive but irrelevant nor relevant but unproductive education is acceptable. Prevailing education is less relevant and less productive than what we could have for its cost.

Increased relevance can be sought at both macroscopic and microscopic levels. A macroscopic view of relevance addresses curriculum. At this level, one asks what the major objectives of the system are and whether these objectives represent the best choices in light of societal objectives and needs. A microscopic view of relevance addresses instructional outcomes. At this level, one asks questions that shade into the productivity domain, such as whether a given outcome is a necessary component of an instructional transit; whether the outcome is sufficiently formulated to permit evaluation of its appropriateness to an instructional transit; and whether student proficiencies referencing to the outcome can be evaluated. The mandated portion of education is legitimized only to the extent that such instruction is relevant at the macroscopic level. Where mandated instruction is macroscopically relevant, the productivity of such instruction turns on its microscopic relevance, which is inextricably intertwined with instructional effectiveness and efficiency factors.

Entertainably, different definitions of relevant education are equally compatible with a productivity engineering effort that is predicated on some one view of a relevant education. That is, alternative views of relevant education all will implicate some motor skills, some verbal information, some intellectual skills, some cognitive strategies, and some attitudes and thus will exhaust the set of learning domains that Gagné (1972) finds exhaustive. Hence, when formulating systems that are

alternative to the prevailing system, such formulations can be based exclusively on productivity considerations, even though these formulations contemplate concurrent efforts referencing to relevance at the macroscopic level.

The prevailing educational system evaluates student progress relative to the class. This evaluation perspective entails the use of a normatively-evaluated instructional group and so is characterized as a NEG system. The foremost deficiency of a NEG system is its evaluation perspective. The pertinent science and technology suggest that all productive alternatives to the NEG system should feature an outcome-referenced evaluation perspective that applies to a sequence of mandated instructional outcomes. Any such alternative system is characterized as an ORE system. An illustrative set of ORE systems is sketched in Section 3. These systems are compared and contrasted with the NEG system and with each other. The set of ORE systems may be viewed either as a progression of systems that is ordered by posited installation dates, or as alternative systems that compete for research and design-development-installation resources, with one or more winners to prevail.

The set of ORE systems is designed to aid decisions on how finite national research and development resources might be focused to ensure that education throughout the next decade or two will be consonant with the educational investment in children and dollars. Entertainably, a decision framework for resolving large questions concerning the form and timing of educational futures entails the sort of structure that the set of ORE systems provides. The structure is prescriptive only in the sense that it assigns different efforts to different systems. It precludes no effort having an evidential or rational basis. However, it invites the decision-maker to avoid the perils of a random resource-assignment strategy. It asks the decision-maker to distinguish between decisions to have and decisions to entertain specified educational futures, to fund alternative systems to ensure that we do not serve society's shorter-term needs at the expense of its needs a decade hence, or vice versa, and always to reject nickel returns on dollar investments. Because it envisions ambitious interdependent efforts that involve R&D establishments and their natural allies in academic and industrial communities, the structure invites diminution of zero-sum game hostilities. For effective interdependent action requires that the cooperativeness of the positive-sum game at least temper the competitiveness of the zero-sum game.

Accepting the view that all alternatives to the NEG system should share the ORE perspective, one must decide how soon each of a set of ORE systems could be available in installable form, what each system will do, and at what costs in R&D and procurement-operation. ORE systems in conceptual form vary for what is promised and when. The top of the line usually will be preferred if one neither has to wait for it nor pay for it. Only when the realities of cost and delay are considered

do choices on such matters become difficult--and realistic. The decision to attain given levels of educational relevance and productivity entails given levels of cost and delay. Pertinent views on educational relevance and productivity and trade-offs between these factors and cost-delay factors are provided in Section II.

II

INSTRUCTIONAL RELEVANCE AND PRODUCTIVITY

Educational R&D is funded to design, develop, and install educational systems that exploit applicable states-of-the-art and so optimize relevance and productivity of instructional and allied (e.g., child care) services, conditional on specified cost bounds. Legislatures mandate common instructional services at the curricular level. It is likely that affected parents, students, and taxpayers will increasingly demand that schools render these services productively. So long as parents are asked to spend educational options, students to spend time and effort, and taxpayers to spend money on mandated instructional services, these investors will ask that the return be consonant with the investment.

It is also likely that the investors increasingly will require that mandated educational services prove relevant to the needs of society and individual. Whereas productivity can perhaps be defined in a timeless sense, the criteria against which instructional services are evaluated for relevance have in the past and should continue in the future to shift or evolve. The prevailing educational system has tended to react ad hoc, ad hominem, and ex post facto to changing views on relevance. There is a need to better anticipate the relevance criteria for mandated instructional services, for the relevance issue appears more than a passing political fad. Moreover, the concept of relevance is not an abstraction that is so remote that it cannot be employed and studied in a technical setting. Educational R&D will be remiss if it does not make instructional relevance coequal with instructional productivity.

INSTRUCTIONAL RELEVANCE

Positing mandated educational services that will prove relevant some years hence is not devoid of empirical-rational meaning and so to some extent is controlled by a state-of-the-art (SOTA). One establishes relevance at the macroscopic level by apprehending responses to such questions as "How should individuals relate to society?" and "How should individuals relate to each other?" Answers to these questions turn on human values. At minimum, a relevance SOTA should determine how these answers will be apprehended.

While questions of relevance are complex, identifying mandated educational services that are more relevant than those provided by the prevailing educational system appears to pose no insurmountable problems. One begins with the view that a totalitarian state will mandate most educational services to serve the state's control and production requirements. Conversely, in an anarchistic state there are no mandates save those that are imposed locally by the laws of the club and the fang. Somewhere in between is the democratic state,

which mandates certain educational services addressing the shared needs of all--perhaps in the domains of social interaction, orientation to earth and universe, and that as yet unnamed science for making the state responsive to the individual--while treating all other services that are legitimate to education as elective options of parent and child. If we opt to perfect the democratic state and to require the educational system to participate in reaching this objective, then that decision alone goes far toward establishing criteria for extent and intent of mandated educational services.

Those seeking instructional relevance should not pander to the interests of a technostructure, whether the technostructure is that of a national bureaucracy, of the educational institution, of an educational R&D enterprise, or of the extended research community. A case in point is currently-taught "modern mathematics."

Entertainably, the different modern mathematics programs now installed in elementary schools lead to greater mathematical sophistication than traditional programs addressing computational skills. Yet many question whether a modern mathematics program does justice to computational objectives. Those who decided to install such programs as mandated instruction during the 1960s either thought that the year 1980 would arrive requiring everyone to be mathematically sophisticated and no one to balance a checkbook or did not bother to think the matter through.

An educational system that is sensitive to relevance requirements should teach computational skills, but still might offer modern mathematics as an elective option. Moreover, it is possible that a decision to install modern mathematics in elementary schools during the 1960s simply was premature and that such instruction, installed in 1980, would meet a relevance test. Meanwhile, the citizenry requires instruction that arms the individual to evaluate the usurous propositions of loan sharks and consumer credit advocates and the arithmetic of food and detergent containers and immunizes informed individuals to the myriad impoverishments that are inflicted on those who are not good at figures.

Modern mathematics programs illustrate that those who design an R&D system or framework of systems must guard against a tendency of technostructures to push available means at the expense of relevant ends, a point well made by Ellul (1967). The implication is that R&D should turn a deaf ear on those who assert that a) productivity issues can be grasped at this time, b) relevance issues cannot as straightforwardly be apprehended or addressed, and c) therefore, the R&D effort should lead from the strength that is inherent in available means and defer on the question of ends.

While recent history casts doubt on the view that a house relatively divided connot stand, the only state than can stand for long in the

absence of a social adhesive that most find binding is the anarchistic state. Whether society is defined as consisting of two individuals or two hundred million, it is a product of its social cement--a shared Magna Carta, social contract, constitution, blood oath, lingua franca, morality, style, xenophobia, or mosaic of such factors. If a collection of individuals is a society, then its members share--with shifting minor levels of demurral across elements of the domain--a set of values, although some may be cherished only in the abstract. The apprehension of common values, then, is a first task of the educational relevance engineer.

Some of a society's shared values are so widely reflected in the community that the child seldom can avoid acquiring them. Values so acquired might be said to result from spontaneous indoctrination. Few crawl up the wall in face of indoctrination of this sort. However, intuition suggests that some values that many would include in the shared set are not acquired on the basis of spontaneous indoctrination.

The choice then is either to secure acquisition of such values by using a more concrete agent of indoctrination or to define the society just on those values that arise spontaneously. This problem arises in the minds of those who would perfect the democratic state. An alternative to direct indoctrination with regard to such values might be to make the case for them in utilitarian or other appropriate terms, just as one would hope that we do not ask children to cherish scientific method because it is a good thing, but rather because it is capable of returning illustratable fruits. Holding in abeyance the nature of these values, we have then the questions concerning how such values might be taught, if at all, and where or by what agent. Four recent publications illustrate the range of views on locus.

Bereiter (1972), Coleman (1972), Ellul (1971), and Bane & Jencks (1972) share a concern about social values. Bereiter asked parents to return to a posited earlier position of responsibility for value selection and instruction. He believes that questions of values within reason are parental prerogatives and also that schools that attempt to teach values will prove ineffective. Coleman believes that parents currently are in a poor position to teach values to children, due to diminished parent-child contact in contemporary society. Ellul calls for a revolution of the mind that, first of all, is a value revolution entailing production of individuals capable of apt evaluation of their situation and of actions that serve both themselves and society. Ellul would have the state neither select values nor impose them. Conversely, Bane & Jencks--whose favorable predisposition toward reduction of economic inequality is consonant with a cherished abstract tenet of a democratic society--believe that the state must impose on individuals the concrete consequences of cherished abstract values. Home, school, and state are alternatively accepted and rejected as value effectors.

Neither locus nor method for instructing values appears a priority matter. The first question is "What values, if any, should be taught?" Ellul's views (1967, 1971) entertainably afford a good starting point for the search for an answer. He offers only a scattering of ground rules for individual conduct that should prove useful--e.g., the notion that "tension between man and society" must be made akin to the scientifically correct "tension between man and matter (or nature)," the notion that "private life must be re-invented" so that "life's true problems are not posed in political terms," and the notion that the individual must be educated to "see the limits and uncertainties of all the information in his possession, the relative aspects of his ideas and opinions, the restricted utility of institutions that must never be exalted, but must not be despised either." Such views take us somewhat below the large abstractions of democracy--e.g., to a point where the conflict between democratic and life adjustment perspectives becomes apparent. However, the production of more relevant instruction requires that such views be given more concrete expression.

Apprehension of shared values yields a basis for defining relevant mandates in both skill and attitude domains. Entertainably, efforts to establish more relevant instructional objectives should reflect both the momentary shared needs of the society and specific implications of national aspirations regarding the social contract. A preponderance of these aspirations is framed by constitutional law. Such law is more visionary than descriptive. From it, one gains the view of a citizen sufficiently proficient in representing himself at the polls, in the marketplace, and in social situations to transform the idea of a democratic state into reality. The society apparently is en route to such a transformation but far from journey's end.

Many institutions probably have a role to play in advancing the citizen toward forms and levels of competence implied by the concept of a democratic state. If the educational system is an important such institution, then its responsibilities do not end with instruction in U.S. history, large abstractions concerning civic behavior, or the three Rs. Some of the ORE system alternatives to prevailing education should intensively pursue the objective of making education more relevant at the macroscopic level discussed above.

INSTRUCTIONAL PRODUCTIVITY

An educational system is a housed executive architecture that, programmed by system installation routines to reflect provisions of the system's pedagogical architecture and then activated, renders relevant instruction and allied services on a productive basis. Instruction is considered optimally productive when it as fully exploits states-of-the-art (SOTAs) bearing on instructional effectiveness and efficiency as applicable cost constraints allow. That is, instruction is optimized for productivity when it optimizes exploitation

of applicable SOTAs consonant with cost constraints. This contrasts with optimization of a SOTA through application of control-optimization theory (cf, Calfee, 1969; Atkinson, 1972).

Although it is useful to distinguish between effectiveness and efficiency facets of a productive educational system, one can go only so far toward production of an effective system without becoming enmeshed in efficiency issues. A fair characterization of an R&D effort to devise productive instruction is that earliest portions of the effort will stress the effectiveness facet of productivity, whereas later portions of the effort increasingly will stress the efficiency facet. Glaser & Resnick (1972) provide a recent summary of the literature grounding a SOTA for effectiveness. Gagné (1972) and Atkinson (1972) illustrate elements of a SOTA for efficiency.[1] The task at hand is not to summarize an extensive literature or to enumerate the totality of pertinent issues that such a literature reveals. Rather it is to consider productivity issues from a standpoint of their implications for devising a framework of ORE systems that might prove useful to the educational R&D decision-making process.

Costs of Instruction

Educational tax dollars are spent on system procurement and operation. The student's contribution to the educational economy is his time and effort. The total costs of instruction are the sum of student and system costs. Instruction is productive when it is consonant with student and system abilities to pay and total costs are minimized through exploitation of applicable SOTAs to the extent that cost constraints allow. Such instruction must, of course, be effective in the sense of transiting the student from an entry proficiency state E that the student brings to instruction to an exit proficiency state X that the system is charged to instill in the student.

A later subsection will deal more definitively with instructional effectiveness. The oversimplification that a single entry proficiency state characterizes given instruction will be employed here. A large set of alternative effective transits should intervene between E and X. Each of these transits should differ from all others in one or more ways. We will be interested only in how such transits differ with respect to length, where length is average student transit time

---

[1] As scientific and technical efforts mature, their taxonomies increasingly become theoretic components subject to empirical verification. We see this trend when we compare Gagné's (1972) five-category first cut on learning domains with, for example, Bloom's (1956) three-category first cut or Scriven's (1967) four-category first cut.

predicated on reasonable student effort. From the student's standpoint, the most efficient of the set of alternative effective transits is the one that yields shortest transit time, where all transits require reasonable student effort. Transit time, then, is the measure of student costs of instruction.

Efficiency engineering that is content to minimize duration of transit time must prove insufficient unless unlimited capital and operating resources are available to the educational system. Entertainably, the system will not be allowed to spend appreciably more of the GNP than is currently allocated to education. If the resources of student and system both are finite, then the efficiency engineering problem is to minimize costs within limits imposed by student and system abilities to pay.

Upper bounds are flexible in the sense that one can always rob Peter to pay Paul. Thus, if we assign the Defense, Commerce, and Agriculture budgets to education, we raise its upper bound handsomely. However, while government changes its priorities from time to time, education's problem is not that it is underfunded, but rather that it is underproductive because too many have been undercerebral. Hence, it appears question-begging to insist that what the educational system currently can afford to spend on given instruction defines an upper bound that is inadequate. Such an upper bound should be in the right ballpark. Moreover, current student expenditures on transit time and effort probably also are as large a share of student resources as should go to education. These resources, thrown against mandated and elective instructional and allied objectives, establish an upper bound for what the student can afford to spend on given instruction. Any savings we can effect on these upper bound expenditures either can be used for additional instruction or passed on to the taxpayer and student.

The efficiency engineering requirement is to minimize the cost of instruction without piercing either the student cost bound or the system cost bound. A cost solution that is a minimal value but which pierces either bound is unacceptable. Every ORE system should accede to this constraint on efficiency engineering.

Entertainably, a high but legitimate system cost that minimizes student cost and a high but legitimate student cost that minimizes system cost both will yield total cost values for instruction that are nonoptimal. If so, then somewhere between these extremes for acceptable system-student cost ratios might occur a <u>saddlepoint</u> that so divides total cost between student and system that total cost of instruction becomes a minimal value. Given that instruction is effective, it will represent no small achievement to identify system-student cost ratios that fall somewhere between the two upper bounds. Cost optimization in the sense of locating a saddlepoint for given instruction is a possibility whose realization probably will not occur

until we have rendered all instruction effective and placed the costs of such instruction within appropriate cost bounds. Saddlepoints should continue to decline with advances in efficacy of efficiency SOTAs.

Somewhere in the system cost bound is a retooling, or installation-procurement, cost. The current educational system investment and future budgets for procurement and operation considered, it appears warranted that we could afford modest retooling now or soon, moderate retooling five years hence, and dramatic retooling a decade or so hence. Such views inspire structures given to the different ORE systems sketched in Section III. A reasonable cost perspective emancipates the efforts to develop new educational systems alike from the economic fallacies that are inherent in "System costs be damned" and "Student costs be damned" points of view. The first of these fallacies is illustrated by one who advocates installation of a system which exploits findings of a research program that seeks to minimize transit time at whatever cost to the system. Such research has a legitimate place in advancing an understanding of human learning dynamics and so merits support within an R&D framework. It does not merit design-development-installation efforts that are unacceptably cost-constrained. The second fallacy is illustrated alike by anarchistic and penurious views of education. Such views throw too much of the burden on the student. However willingly, they also sacrifice effective education, which is the only kind of education worth having.

Effective Instruction

Rounding oval tracks is one of the things that racehorses do. Racehorses vary for rate of advance around such tracks. On the theory that the economics of the horse-racing enterprise is optimized to the extent that it is difficult to say which horse will win a given race, handicappers use load differentials that make rate of advance more equal. Horses are differentially loaded on the basis of prior performance. Amateur golfers also are handicapped to make their chances of winning more equal. Here, however, the handicapper uses stroke differentials that reference to proficiency rather than rate.

That a racehorse is a bit slower than other racehorses when rounding an oval track does not argue that the horse is a slower eater or slower to learn where the oats are located. That a golfer is a bit less proficient on a golf course than other golfers does not argue that he is slower at tallying scores or slower to learn where sand traps are located. If cross-task correlations in rate or proficiency exist, these must by empirically established.

Children also come to given instruction differentially proficient at entry and differentially predisposed regarding rate of advance. Whether these tendencies transfer to other instruction also is an empirical question--and one we need not pursue here.

It is useful to regard an exit point X, referencing to a given activity, as the same finish line for all racehorses, the same par score for all golfers, or the same set of mandated proficiencies for all students. However, an entry point E seldom will be the same point, whether for racehorses, golfers, or students. Effective instruction must feature something that is analogous to handicapping racehorses and golfers--but for both entry proficiency and rate of advance, rather than for one or the other.

The arguments for individualized instruction are that specified instruction will prove ineffective unless the alternative transits E_1-X, E_2-X, . . . , E_n-X are permitted and some or all of these transits are permitted to be negotiated according to alternative rates R_1, R_2, . . . , R_n. The empirical base does not yet exist for determining how many alternative transits through given instruction and how many alternative rates for negotiating each such transit effective instruction will require. In many instances, more than one transit and more than one rate per transit should prove required. Whether conventional classroom organization can accommodate multiple-transit, multiple-rate instruction depends on how many transits and rates per transit are required. Those who favor highly-individualized instruction believe that the number of transit-rate combinations should approach in number the number of students receiving instruction. Conversely, the conventional classroom can handle a few transits per unit instruction and a few rates per transit, particularly when the larger school organization is brought to bear.[2]

---

[2]The tendency of a local NEG school to accommodate to a multiple-transit, multiple-rate instructional requirement suggests that NEG schools can manage some degree of systematic individualization. This school engages in extensive testing during the first few weeks of the school year. On the basis of student performance on nationally-normed tests of various sorts, the conventional grades are partitioned into higher and lower proficiency groups. K-1, 1-2, 2-3, 3-4, 4-5, 5-6, and 6X classes then are formed such that lower-proficiency 1st graders are grouped with kindergarteners, higher-proficiency 1st graders with lower-proficiency 2nd graders, etc. Groupings are sufficiently large that three teachers instruct each grouping in a pair of classrooms. The different teachers teach in different skills domains. A grouping is multiple-tracked by skills domain on the basis of the same test data that are used to effect the grouping. Reclassification to different tracks occurs as teacher judgments of proficiency require. The productivity of instruction is unknown. Nor is it relevant here. What is of interest is that the school apparently is managing to organize itself consonant with individualizing instruction to a greater extent than advocates of individualized instruction typically acknowledge is possible.

System Accountability

Two fundamental ideas permeate modern pedagogy concerning how to increase productivity of mandated instruction. The first of these ideas is to make the educational system more accountable for educational production. The second is to render instruction more productive through individualization that takes pertinent characteristics of the student into account. The ORE system alternatives to be presented all contrast with the generic prevailing, or NEG, system for accountability. The different ORE systems contrast with each other for extent of individualization of instruction.

Accountability is preliminarily discussed below and is treated in somewhat greater detail in Section III. Accountability is a function of instructional evaluation perspective and practices that stem from such a perspective. The NEG system features normatively-referenced evaluation. Grades leave the classroom. The proficiency data underlying grades typically do not. System performance is, for long stretches of instructional time, somewhat hidden under the mask of a relative A-to-F evaluation scale. Where personnel perform with extreme ineptitude over a long enough period, the community in time will pierce the A-to-F student grading mask and assign the F to the system that it warrants. The system, then, is accountable for massive failure. However, lesser failures--e.g., the failure of given instruction referencing to given students--will not be detected outside the classroom, and often will not be detected even in the classroom. Such failures the NEG system is able to assign to the student. In such instances, some students may fail, but the system projects success so long as it can sell its A-to-F distribution of student grades to the community. No alternative to a NEG system is worth considering that does not throw out the generic system's approach to evaluation and so to accountability.

An ORE system requires system personnel to accept responsibility for transiting the student from E to X, where progress along the transit and acquisition of exit proficiencies are reflected by the student's performance on outcome-referenced tests. ORE system grading is quantitative rather than qualitative. It reports proficiencies achieved in a given skills domain in given instructional time. According to the ORE perspective, the system fails when the student manifests subcriterion proficiency. ORE tests permit failures of instructional management to be detected with sufficient speed to preclude advancing students to new instruction until system failures of current instruction are overcome. Developers of ORE systems should provide fair standards against which to evaluate the system's rate of transiting students through mandated instruction. Simply because it employs and exploits outcome-referenced evaluation, an ORE system should prove appreciably more accountable than is the generic NEG system.

Individualization of Instruction

Mandated instruction can be individualized along two axes, herein labelled differential pacing and alternative transiting. A commitment to

differential pacing assumes that a specified transit throught specified instruction will be effective for some students if the instruction is presented at one rate and for other students if presented at another rate. A commitment to alternative transiting assumes that a specified transit that exits at specified instructional outcomes will be effective for some students if the transit consists of initial instruction and for other students only if initial instruction is supplemented on evidence that initial instruction fails.

In the absence of differential pacing, initial instruction should prove ineffective for some simply because the instructional pace exceeds the student's ability to track, store, process, respond, etc. If, during supplemental instruction that follows failed initial instruction, instructional rate again is insensitive to student capability, the supplemental instruction also should prove ineffective. Fortunately, this outcome is not highly probable, apparently because the student responds to portions of instruction that is presented at an excessive rate. In effect, the student reduces presentation rate by treating sequences consisting of initial and supplemental instruction as a single presentation. Oversimply, the student may apprehend half of what is presented during initial instruction and the rest during supplemental instruction. Entertainably, a lowered instructional efficiency that levies increased costs on system and student often will result when supplementation is substituted for differential pacing. Absence of differential pacing also tends to waste the time of students who are capable of accepting presentation rates that are in excess of the rate that is employed by a single-rate system.

There are alternative ways to differentially pace students. System-controlled differential pacing paces presentation conditional on prior pertinent student performance. An alternative is student-controlled differential pacing. Unless the system has identified and instituted those conditions that predispose the student to optimize instructional pace consonant with his capability--that is, to do his best--instruction may be less than optimally efficient when rate is student-controlled. Entertainably, system-controlled differential pacing is most apt to mandated instruction, while student-controlled differential pacing is most apt to elective instruction.

A system that appreciably differentially paces instruction essentially must function as would a tutor while experiencing per student costs of a group instructional system. Extensive differential pacing apparently requires an automated or semiautomated system that would perform as well as a multitude of tutors under operating cost constraints akin to those for NEG system operation.

The extent to which instruction should be differentially paced presently is unknown. Entertainably, some instructional outcomes will necessitate little (or gross) differential pacing, whereas other outcomes might necessitate as much differential pacing as the more-committed advocates of computer-assisted instruction imagine.

In its simplest form, supplemental instruction simply repeats initial instruction. Repetitive supplementation appears most appropriate in motor learning tasks and when two or more items of verbal information are to be associated. In paired-associates learning, one rate of presentation typically characterizes all students, with rate differentials taken as differences in number of items acquired per trial. Item order typically is randomized from trial to trial to preclude learning that is assisted by local dependencies holding between adjacent items. Formerly, a paired-associates list would be presented as a (randomized) whole across trials until criterion proficiency was reached. Nowadays, it is found efficient to approach paired-associates learning somewhat differently, within a framework of partial repeated presentation across trials.

The current approach (cf, Atkinson, 1972) differs from the earlier pre-Rockian one in making use of a dropout procedure grounded on testing for both short-term and longer-term effects across trials. Randomization ignored, the former approach defines a set of effective transits as the set of trials to criterion. The current approach--which requires equipment and organization not available to the generic NEG system--defines a set of effective transits that tends to have as many members as there are students who receive instruction. This is because, on a given trial following the first, different students will cause different items to drop out, so that the second and later trials will tend to present different items to students even when the same number of items is presented.

A generic alternative to repetitive supplementation is instruction that augments initial instruction. Augmenting supplementation appears most appropriate when terms referencing to concepts or constructions referencing to concepts, rules, or algorithms are to be comprehended and initial instruction fails. Various forms of augmentation may be discerned. One is to reduce key terms to reach or more nearly approach an assumed data language level. A second is to reduce surface structural complexity or complexity of an alternate means for representing relations. A third is to introduce analogies that more concretely portray systemic functions of a construction. Perhaps a fourth is to employ a logic that occurs at a lower level in a maturational progression. Whatever its form, augmenting supplementation seeks to aid comprehension by referring the instruction to entry proficiencies that are beneath or collateral to those that initial instruction assumes.

In the absence of alternative transiting of given instruction, the instruction should be ineffective for some students because it assumes too-abstract terms or too-complex constructions are fundamental or because it assumes too-broad collateral instruction. These objections might be overcome by designing initial instruction to ground on the entry proficiency of the student who requires the greatest supplementation. Apart from the difficulty of determining this point at little cost, the effect of initial instruction so designed would be to render the

instruction inefficient for most, by requiring them to transit much instruction that addresses already-mastered outcomes.

As with differential pacing, alternative transiting in an advanced form asks the system to function akin to how a tutor functions while experiencing per student costs of a group instructional system. The extent to which instruction should exploit the alternative transiting notion is presently unknown. It is entertainable that students will reach some outcomes on a productive basis only if the alternative transiting notion is maximally exploited, whereas other outcomes will be productively reached in consequence of more-modest or slight exploitation of the notion.

Evaluation of Instruction

According to an ORE perspective, whether initial instruction succeeds or fails is determined by student performance on an outcome-referenced test. Such a test can vary for the pertinent information that it conveys. The least information that a useful test might convey is that initial instruction succeeds or fails. Next up on the scale would be a test that localizes the region of failure. At the top of the scale would be a test that signifies what to do about localized failure. Present state-of-the-art is entirely consonant with development of tests of the first type, somewhat consonant with development of tests of the second type, and inadequate for development of tests of the third type. Tests of the first type are failure-detecting; of the second type, failure-localizing; and of the third type, supplementation-specifying.

Given a commitment to transiting all students through mandated exit outcomes, the failure-detecting test, when failed, compels that supplemental instruction occur, although scope and form are not specified. When such a test is failed, it is probable that the instructional manager will elect to have supplemental instruction treat the same domain as initial instruction. The form of supplemental instruction will be selected on an intuitive basis from a range of alternative possibilities. The insightful teacher in such a situation might exceed a trial-and-error level of efficiency when seeking to identify apt supplementation.

The failure-localizing test, when failed, pinpoints the domain of failure of initial instruction, but does not specify the form that supplemental instruction should take. Again, intuition must be pressed into service during selection from among alternative supplementation possibilities.

The failed supplementation-specifying test localized failure and specifies the form of apt supplementation. Such tests are currently top-of-the-line. Their extensive development presupposes more information than is yet available. Their extensive use in education presupposes an appreciable capability of the system that employs them to accommodate individualized instruction.

III

PREVAILING AND ALTERNATIVE GENERIC EDUCATIONAL SYSTEMS

NEG AND ORE notation distinguish between the prevailing and alternative generic educational systems (ESs) on the basis of evaluation perspective and practices. ORE systems may be further distinguished on the basis of how they exploit differential pacing and alternative transiting notions to yield more productive instruction. The NEG system is an ES_0 whose alternatives ES_1 through ES_n are intuitively ordered for date of installation on the basis of magnitude of the R&D effort that each system in the progression seems to imply and on the basis of costs of installation for each system, which appear correlated with magnitude of effort. Intuitions on magnitude of effort are grounded on the assumption that the progression reflects a scale of increasing productivity for educational systems, where system and student costs determine the total cost of transiting students to specified proficiencies. It is not assumed that we must design, develop, and install each system in the ORE system progression--with ES_1 supplanting ES_0, ES_2 supplanting ES_1, etc. Nor is it assumed that the progression will withstand the implications that new knowledge has for the form of a conceptual progression. Rather, the progression frames currently perceivable options and invites the cross-the-board efforts that will either establish the tenability of all or some of these options or show the way to new options. Finally, the progression is grounded on an ES_1 that we can have soon if a) the NEG system is considered all that much inadequate and b) the conceptual top-of-the-line defines an effort that we cannot hope could result in an installed system having top-of-the-line productivity for several years.

THE GENERIC NEG SYSTEM

The generic NEG system underachieves levels of instructional relevance and productivity that it could reach if it exploited applicable SOTAs conditional on cost and other constraints imposed on NEG. These constraints impose a physical facility primarily appropriate to group instruction, certain mandated but poorly defined instructional outcomes, specified entering students, and specified duration of instructional transit.

NEG system instructional management failures within the classroom are almost impossible to detect, apparently for two reasons. First, mandated instructional outcomes are poorly defined. Hence, the mandated outcomes do not rule out any of a wide variety of achieved system performances. Second, children in the instructional group (or classroom) are normatively rather than absolutely evaluated for attained proficiencies. This evaluation perspective effectively makes the child rather than the teacher or the system responsible for progress in the classroom. A primary

objective of an R&D effort to develop an ES$_1$ alternative to the NEG system might simply be to apply a changed intraclassroom evaluation perspective that ensures detection of system failures in instructional management.

As the NEG system inherently prevents too many youngsters from looking good instructionally, so it inherently condemns too many teachers. For it is impossible for all NEG system organizations to show up well when a population of NEG classrooms is contrastively evaluated using a nationally-normed test. When such a test is used to evaluate classroom level instructional management effects across NEG system classrooms, then nearly half of the classrooms must reveal an achieved instructional management effect that falls below the average for all classrooms in the sample. The public has been persuaded that classrooms, school districts, or states falling below the average manifest instructional management failure. This even though it cannot be otherwise if the classrooms distribute for average test proficiency, which they will if classrooms are not homogeneous for student input and educational resources expended.

Interclassroom comparative evaluation conceivably is of value when instructional management failure is widespread and evaluable. Administrative responses to instructional management failure then become a function of degree of failure. However, fair interclassroom comparative evaluation assumes that one of two conditions prevails: a) the entry proficiency of children is identical across classrooms; b) if not, the instructional management effort that characterizes each classroom is baseline-referenced to the classroom's particular entry proficiency as origin of the effect. Differentials in instructionsl management effect then, by definition, become differentials in instructional resources expended in the different classrooms. Given that interclassroom evaluation is fair, the ideal situation would be one in which all classrooms performed optimally productively--the dead heat that equal educational opportunity implies when individual differences are averaged out.

By contrast, NEG system interclassroom differentials in average test score may be due: a) to the different districts, schools, or teachers perceiving and teaching to different instructional outcomes that apparently are consonant with ambiguous mandates, b) to different entering student proficiencies, c) to differential use of instructional resources (with consequent differentials in instructional management effect), or d) to a combination and/or extension of these factors.

NEG education suffers because it is not explicitly enough committed to transiting the student to specified instructional outcomes or to an evaluation perspective that separates instructional management effects from other effects. Whether one believes that more productive schools entail greater individualization or personalization of instruction, improved relevance, wiser differentiation between what the schools can and cannot do, a decrease in mandated instruction, or performance contracts, the schools probably will not become more productive until

they are provided with an apt and unambiguous basis for evaluating instructional management performance and they are required to share the findings of such evaluation with parents.

ORE SYSTEM ALTERNATIVES TO NEG

In contrast with the generic NEG system, every ORE system will feature outcome-referenced evaluation that indicates how productively the system manages its mandated instruction. The different ORE systems should contrast with each other for relevance and productivity. They should differ for: a) degree of relevance of mandated instruction at the macroscopic level, b) range of choices provided for elective instruction, c) capability to reach apt (which is not necessarily maximal) individualization of instruction, and d) informativeness of proficiency tests.

In consequence of system characteristics, particularly with regard to the informativeness of proficiency tests, the different ORE systems also should differ in extent to which personnel are assisted to reach the level of instructional productivity that is inherent in the system. For, whereas the NEG instructional manager is an essentially-unassisted teacher, the manager of instruction in some future system might function primarily by issuing commands to paraprofessionals and hardware, intervening directly only on detection of lower-level cupidity or stupidity.

The progression of ORE systems to be sketched should be viewed as illustrative. If less tenable than an alternative framework, then it will engender concrete counterproposals against which it can be evaluated.

A First ORE System (DPG)

The dominant organizational feature of the NEG system is that of the diverse proficiency group (DPG). Were there a generic organizational alternative to a NEG system having this organizational feature, then one would need refer to a NEG system having the feature as NEG DPG. Since alternative generic forms of organization do not exist for prevailing education, the system is sufficiently characterized as NEG.

Conversely, the ORE systems to be sketched differ appreciably for organization of the instructional situation. The most-quickly attainable ORE system alternative to the NEG system is one that essentially retains NEG organization of the instructional situation. This system is denoted ORE DPG or, where ORE is understood, simply DPG. Because it trades away longer-term promises for gains in time

and cost of installation, some will consider the DPG system unduly unglamorous.[3]

A major objective of the DPG system is to ensure apt evaluation of student proficiencies, with periodic transmissions of the information that such evaluation generates to teachers, administrators, and parents. Explicated relevance bounds for mandated instruction should guide production of an m skills domains x n year levels set of instructional outcome sequences across which the system is required to transit students. State-of-the-art for development of failure-detection tests (FDTs)--criterion-referenced proficiency tests that indicate success or failure of instruction but not the precise locus of failure or what to do about it--should be exploited to yield m x n FDT sequences.

Each FDT sequence should be evaluated for sequential aptness and calibrated to the instructional transit time dimension--a complex effort that is sketched in the Technical Appendix ection of this document. In consequence of calibration, a u instructional units x m x n set of FDTs is developed. Each FDT addresses outcomes for an instructional unit and reflects criterion performance standards for the unit. The data that administration of an FDT yields reflects achieved instructional management performance. Such data, suitably processed, reflect system performance referencing to the student, class, school, district, or higher administrative unity. The processing of FDTs and dissemination to teachers, administrators, and parents of information that compares achieved with criterion performance poses processing-reporting requirements that exceed the processing-reporting requirements characterizing NEG. Hence, an automated processing-reporting system probably will be required to preclude unacceptable rises in costs to the system.

It is suggested from time to time that American education places a competitive stress on children that is injurious to mental health. To the extent that this is so, it is a problem for parents, the community, and the schools alike. Transferring the primary responsibility for transiting students through mandated instruction from student to school seems a logical first step in the amelioration of any such problem.

---

[3] At some point in a discussion of systems, it is necessary to distinguish between the operating system and its underlying plan. Thus, one distinguishes between an abstract system or component in designed-developed form and its application in installed-operational form. Wherever the distinction is necessary, we denote an entity having design-development reference by an expression in upper-case font, without underlining or italicizing. Conversely, a corresponding entity having installation-operation reference is denoted by an upper-case font expression that is underlined or italicized. Thus, NEG is an existential entity in installed-operational form. Although inexplicit, NEG has a NEG correspondence that is an underlying abstraction. However an ES_1, whether viewed as DPG or DPG presently is only a conceptual entity. Since the distinction needs to be made only in a Technical Appendix, we will continue to denote NEG as NEG.

A DPG system probably could be justified if it did no more than ensure greater accountability on the part of the system. This necessitates that the system reflect an increased relevance at the microscopic level for now-mandated instruction through more-explicit specification of instructional outcomes and removal of frivolously and personally inspired outcomes. However, it is contemplated that the effort to develop a DPG system also should bring applicable SOTAs to bear on redesign of the instructional management operation to improve its productivity. That is, the contemplated DPG system should cost-conditionally perform SOTA-optimally for instructional relevance, effectiveness, and efficiency.

Cost specifications for the DPG system should for the most part be NEG-referenced. The R&D effort should accept the generic NEG facility, essentially accept NEG operating costs, and essentially accept installation costs that are consonant with NEG resources. The DPG system should be so designed that conversion from NEG entails capital outlays that are both justified and achievable during the years immediately ahead.

An effort to develop a DPG system probably should be constrained by an extant knowledge base, by an apparent need to salvage as much as possible of the multibillion dollar capital investment that society has in the NEG system, and by an associated requirement to produce a system whose operating costs represent no larger a slice of the GNP than the NEG system expends. Finally, it should be constrained by the requirement that we get on with it, rather than accepting the added penalizing delay that is inherent in developing and installing an appreciably more-productive system.

Although DPG is far from an ultimate system, the R&D effort that develops it would need resolve several challenging technical questions before the system could be completed. First, it would be necessary to decide how the transit time that is available to the system--e.g., NEG system K-6 transit time--should be apportioned among mandated instructional objectives, elective instruction, and mandated extrainstructional services (e.g., child care, as discussed by Bereiter, 1972).[4] Second, the R&D

---

[4]Assuming that all students will continue to be required to spend the same amount of time in school, then an interesting consequence of a commitment to individualize mandated instruction--which proponents of ORE systems of every type must make--is a corollary commitment to champion appreciably elective instruction or alternative activity in school. For individualized instruction addressing shared mandated outcomes cannot work unless the student who reaches such outcomes ahead of the last of his fellows has somewhere to go. This may be one of those rare cases where technology promotes democracy. For the mechanics of individualized instruction tend to place a ceiling on how much can be mandated. The R&D effort might carry this one step further by specifying a ceiling on mandated instruction such that no student will be deprived of appreciable experience

effort would need apprehend fair standards against which to evaluate instructional management performance. Third, the effort would need discover how inexpensively to exploit current state-of-the-art for outcome-referenced proficiency testing so that cost-attractive evaluation of instructional management effects is achieved. These difficulties also face those who would produce ORE systems of more advanced design, but more persistently and as part of a larger set of problems requiring resolution.

The strengths of the envisioned system are that: a) it is an ORE system and so appreciably more accountable than the generic NEG system; b) it represents an advance for instructional relevance and productivity that need not wait for extensive increases in power of the applicable SOTAs; c) because it is compatible with much of the capital investment characterizing the NEG system and operable at the level of NEG system operating costs, it assuredly could be installed during the years immediately ahead.

A Second ORE System (HPG)

The homogeneous proficiency group (HPG) is a notion introduced by Kriewall (1969) as a compromise between group-organized, or DPG, instruction and individualized instruction. An HPG system retains the diverse proficiency group--at a classroom or interclassroom level--as an outer shell for sets of homogeneous proficiency groups that may be alternatively populated for purposes of instruction in the different skills domains.

The periodic use of failure-detecting tests (FDTs) to evaluate the student's achieved proficiencies against mandated outcomes implies that the instructional manager might need to deal differentially with two or more subgroups of the DPG instructional organization when rendering instruction in a specified domain. That is, following instruction and testing of a specified instructional unit of a specified year level for a specified skills domain, the class might divide into those who reveal criterion proficiency for the unit (and so might advance to elective instruction) and those who reveal subcriterion proficiency and so require supplemental instruction addressing unit outcomes. When this happens in a DPG system, it is left to the instructional manager to decide how the class, and particularly those for whom initial instruction fails, will be organized and what form supplemental instruction will take. As presently conceived, an HPG system would deal more definitively with the organizational question and would localize scope of failure of initial instruction through use of failure-localizing tests (FLTs).

---

in the elective domain. The NEG system's accelerating child easily outstrips customary mandates, whereupon it is probable that he gains some measure of independent action. Such reward is seldom bestowed by NEG on the slower child, whose sense of failure in the mandated instructional domain probably is intensified because opportunity for freer action in the elective domain is curtailed for those that NEG insinuates fail in the mandated domain.

At minimum, the HPG system would take the DPG class--25-30 students who are conventionally leveled at one of the K-6 year levels--as an outer organizational shell. A maximal outer shell would be provided by the K-6 school, which would be free to constitute year-levels non-conventionally for purposes of instruction. We illustrate HPG using a conventional class as the outer shell.

Imagine that mandated instruction subsumes six skills domains--reading and mathematics are illustrative--at a year level of interest and that the instructional program addressing outcomes for each skills domain occurs as a 10-12 unit sequence. Let a unit be considered mastered when a student reveals criterion proficiency on a suitable FLT administered following instruction. Let beginning-year performance on FLTs testing prior-year instruction in each skills domain be used to assign students to HPGs in each skills domain. Let approximately three HPGs be allowed per skills domain. The HPG system that is consonant with these assumptions should be more productive than a DPG system because HPG organization allows greater individualization of instruction and, by substituting FLTs for FDTs, supplies more useful information underlying individualization of supplemental instruction.

The envisioned HPG system is a multitracking system, but not a typical one. Assignment to tracks would be independently effected across skills domains. The accelerated arithmetician then would not necessarily be an accelerated reader. There would be no "general intelligence" branding of children. Thus, at a given point in instruction, a student conceivably would distribute across available "rate tracks," for example, falling in Track 1 for two skills domains, Track 2 for two others, and Track 3 for the two that remain. Moreover, periodically--e.g., quarterly--students might be reassigned consonant with changes in FLT-defined progress. The power of this scheme would increase as the outer shell of the HPG organization is extended to include two or more conventionally year-leveled classes. It would increase still more if such classes were year-leveled on the basis of apt measures of beginning-year performance--somewhat akin to the regrouping tendencies (described in Footnote 2) of a local NEG school.

The envisioned HPG system makes no assumptions concerning the stability of rates of progress over time, rate homogeneity of the student across skills domains, or homogeneity of the class for relevant entry skills. It may group to homogenize for momentary instructional purposes. Where it does, homogeneity results from test performance rather than from rate-proficiency assumptions. Since the system imposes a cost in grouping-regrouping that is not explicit in NEG and ORE DPG systems, a modest extension of the DPG processing-reporting automation requirement may be needed to ensure that the envisioned system operates at or near the NEG cost level.

The envisioned HPG effort may be characterized as follows. First, whether HPG is developed as a follow-on to DPG or as an alternative to

DPG, it should accept essentially the same extant exploitable knowledge base. Second, the system should improve upon DPG capability for individualizing instruction through more-explicit and more-systematic grouping-regrouping of students and the use of more-informative failure-localizing tests. Third, its mandated instructional domain should be less extensive than that for DPG because increased individualization requires this. Finally, the HPG effort should perhaps make available alternative forseeable sets of supplemental instruction that might prove appropriate when initial instruction fails. The envisioned HPG effort so characterized requires a greater production effort than does the envisioned DPG effort. Its installation costs should be modestly greater--both in dollars and the efforts of personnel to accommodate to the new system. However, production of the envisioned HPG system probably requires little in the way of additional new knowledge.

The system would handle the same volume of test data as would DPG and would report to the same audiences. It would exceed DPG regarding instructional management assistance functions--particularly with regard to grouping-regrouping. Minimizing grouping-regrouping as an HPG instructional management activity--or as an administrative activity necessitating a larger administrative staff--probably requires automated data processing that goes modestly beyond the DPG requirement.

What Other ORE Systems are Required?

An installable educational system results when a scientific and technical knowledge base--or set of applicable SOTAs--is exploited in advanced design-development and articulation activities that are required to engineer such a system. Directed research and exploratory design-development activities establish the knowledge base that system development exploits. Thus, two broad sets of R&D activities contribute to realization of an installable system. One yields applicable SOTAs. The other exploits these SOTAs. The range of directed research and exploratory design-development activities that yield applicable SOTAs are herein classed as exploratory R&D. Systems in preliminary formulation give direction to and, in time, modify to accommodate findings of an exploratory R&D effort. Such systems class in the exploratory R&D domain. The range of advanced design-development and articulation activities that exploit applicable SOTAs to yield an installable system are herein classed as advanced R&D. Such activities assume new knowledge only occasionally, and then only in the narrowest technical sense. The systems that these activities address class in the advanced R&D domain.

The envisioned DPG and HPG systems essentially are predicated on already-existing knowledge bases. Hence, these systems class in the advanced R&D domain. Development of an operating realization of each system could be carried forward, with minor directed research and exploratory development detours, to completion on the basis of existing

knowledge. More powerful ORE systems can be perceived in faint outline. We wish to place representative such systems in the exploratory R&D domain, on the assumption that directed efforts addressing such systems in preliminary formulation will ready them for transfer to the advanced R&D domain appreciably ahead of the time at which they would qualify for transfer if efforts on their behalf remained essentially undirected.

It is assumed that a preponderance of the resources that are available to educational R&D will be allocated to development of systems occurring in the advanced R&D domain. However, longer-term progress of the enterprise should suffer if serious attention is not devoted to alternative systems that, not yet ready for advanced design-development and articulation, reflect the knowledge gaps that, filled, ensure that such systems can be developed in useful form. The exploratory R&D effort of educational R&D should identify these systems in preliminary form, identify applicable SOTAs, encourage desired advances in these SOTAs, and, to a degree, participate in securing these advances. None of these activities fall exclusively in the purview of R&D. However, the R&D institutional stake is such that R&D should accept primary responsibility for identifying potential advanced systems and applicable SOTAs and for encouraging desired advances in these SOTAs. The responsibility of R&D organizations for participating in securing desired advances in applicable SOTAs should be secondary and indeed will be secondary if the external research community is cooperatively inclined.

The envisioned DPG and HPG systems seek to increase a) instructional relevance at the microscopic level by better explicating terminal outcomes and effective transits leading from student-defined entry proficiencies to proficiencies defined on terminal outcomes, b) system accountability by referencing system evaluation to the rate at which the system transits students to proficiencies defined on terminal outcomes and through periodic transmission of accountability information to teachers, administrators, and parents, and c) system productivity based on improved accountability, more effective-efficient organization of instructional content consonant with the pedagogical knowledge base, and somewhat more individualizing organization of the instructional situation.

We wish to populate the exploratory R&D domain with systems that reflect foreseeable desired characteristics that the envisioned DPG and HPG systems do not have. These include: a) proficiency tests that are supplementation-specifying, b) appreciably improved relevance at the macroscopic level, c) improved organization of instructional content based on a more-powerful pedagogical knowledge base, and d) a capability for more-nearly optimizing individualization of instruction. How finely we will distinguish systems in the exploratory R&D domain turns in part on whether a decision is reached to develop the DPG or HPG systems or both. A decision to develop a system now in the advanced R&D domain frees the R&D enterprise to view development of a follow-on

system as somewhat less imperative than an alternative decision to first bring a potentially more powerful system into the advanced R&D domain as a prelude to development. The first decision probably favors a somewhat less analytic differentiation of systems that are currently appropriate to the exploratory R&D domain than the second decision, which should compel giving immediate careful attention to selection and nurturance of at least one system that one could hope soon to place in the advanced R&D domain.

Because it appears less than optimal to demand new knowledge as a prelude to development of any system that is alternative to NEG, it is assumed here that efforts to develop one or more systems now in the advanced R&D domain will go forward even as we attempt to gain the new knowledge underlying development of potentially more powerful systems. DPG and HPG development efforts promise to resolve a variety of technical problems that these systems share with more advanced alternatives. Many of these problems do not require new knowledge in any profound sense. Rather, they require the dogged efforts that delight engineers and depress researchers. Whether such development efforts should result in installation of the systems that are developed or simply feed to development of a more advanced system is a decision that does not have to be reached now.

New experience invites the review of old decisions. Hence, present decisions do not commit us to a course of action that cannot be modified or overturned as new evidence warrants. In this spirit, we might decide to develop a new DPG system now, to transition to development of an HPG extension of DPG when the DPG development effort is completed, and to focus an exploratory R&D effort on potentially more powerful ORE systems concomitant with the advanced R&D efforts to develop DPG and HPG systems. The alternative consequences are:

1. DPG will be installed as a successor to NEG at Time T--e.g., four years hence. DPG will be modified to HPG and HPG will be installed as a successor to DPG at Time T + N--e.g., six years hence.

2. DPG will be developed but not installed. Development of an HPG extension of DPG will follow. In light of the saved installation effort that is realized by not installing DPG, HPG will be installed as a successor to NEG at Time T + N - 1--e.g., five years hence.

3. DPG-HPG development will occur but without installation. The HPG development effort will feed to development of a more powerful system, now classing in the exploratory R&D domain, that stems from the knowledge base that is available when development of HPG is completed--e.g., the knowledge base that is available four years hence. The more-powerful system will be installed as a successor to NEG at Time T + 4--e.g., eight years hence.

We can increase time to installation of a first alternative to NEG indefinitely as ambitions concerning power of the system increase. What do we do in the interim? If it is true that installation decisions can be deferred and that an effort to develop any system will contribute to development of more advanced systems even if the first system is not installed, then it appears likely that one should always opt to develop the system that is currently most developable. The cost constraints for such a system probably should be those that likely will characterize education on the installation date that is projected for such a system. Hence, we assume that either or both DPG and HPG systems will be developed. Systems to be placed in the exploratory R&D domain are formulated conditional on this assumption.

If we choose eventually to install a DPG or HPG system, then installation costs alone probably would preclude supplanting such a system rather quickly thereafter. Therefore, we define a third system--ES_3--as predicated on the knowledge base that exploratory R&D efforts will make available five years hence and a fourth system--ES_4--on the knowledge base that such efforts will make available a decade or more hence. Should a decision be reached a few years hence to bypass installation of DPG or HPG--e.g., in favor of installing an ES_3 at the earliest possible time--then events might favor advancing schedules for exploratory and advanced R&D and installation for ES_3 and other systems falling at present in the exploratory R&D domain.

The present view is that ES_3 and ES_4 in preliminary formulation should currently occur in the exploratory R&D domain. These systems--third and fourth in the set of R&D systems herein described--are preliminarily sketched below.

A Third ORE System (HPG_2)

Now-developable DPG and HPG systems are ES_1 and ES_2, respectively. The third system--ES_3--is viewed as a compromise between ES_1-ES_2 and an ES_4 that represents the "ultimate formulation" of which current vision appears capable. Assume that ES_4 will individualize instruction, where needed, appreciably beyond what can be accomplished under HPG organization, that it will feature multiply-sited education consonant with technical advances in communications, and that it will in general do every other usefully innovative thing that the reader ever has heard about. ES_3 is viewed as predicated on HPG organization and so is denoted HPG_2. It is assumed that HPG_2 now is in the exploratory R&D domain and that the system will transfer to the advanced R&D domain five years hence, in consequence of knowledge that an intervening exploratory R&D effort adds to the base. New knowledge conceivably will necessitate that the system be reformulated before gaining entry to the advanced R&D domain.

A major problem that the HPG_2 effort could be expected to dent over a five-year period is that of increasing relevance at the macroscopic

level. Comments on relevance in Section II apply. It is assumed that a major charge to the HPG_2 effort will be to register progress regarding macroscopic relevance.

The major implication of Gagne's (1972) five learning domains formulation is that there are five pedagogies, which share some features and not others. Efforts that are in the spirit of Gagne's views are underway in R&D settings. Such efforts should be encouraged and focused, consonant with organizational and scheduling constraints for HPG_2, to contribute the best set or matrix of pedagogies we could hope to ground HPG_2 development upon.

Whether the HPG_2 exploratory R&D effort should be more extensive depends on the resource level that is available to the effort. The effort would prove useful if it accomplished no more than is outlined above.

A Fourth ORE System (IMI)

We come now to those knowledge horizons that all find exciting until cake is placed on one side of the scales and candle on the other. In keeping with the prior tendency to characterize alternative ORE systems in terms of how the instructional situation is organized, the envisioned ES_4 is denoted an IMI system because its most prominent organizational feature is that of individually managed instruction.

The NEG, DPG, HPG, HPG_2, and IMI systems all interact to some extent with the individual student. However, the NEG and DPG systems feature minimal interaction between an instructional manager and a student. The HPG and HPG_2 systems feature an intermediate level of interaction, where needed. The qualification "where needed" should not be taken lightly. The view that instructional interactivity should be maximized to make it optimally productive--whether in the sense of minimizing student costs or total costs--must be regarded as a faith statement on the basis of its present evidential base. It is not precluded that we will in time discover that optimal interactivity is maximal interactivity, which is to say that optimal interactivity is not a function of what is to be learned. In the interim, the qualification "where needed" is in order. Hence, we view the IMI system as featuring a maximal level of interaction, where needed.

Should it prove the case that minimal interaction sometimes is required, then NEG and DPG systems will have shown how to organize the instructional situation to achieve interaction at this level. Should intermediate interaction also be required, then the HPG and HPG_2 systems will have shown how to organize to achieve this level of interaction. Assuming that maximal interaction will be required in many instances, it

remains for an IMI effort to accomplish this level of interaction on a productive basis. Should it prove the case that a system should permit the instructional situation to be alternatively organized on different occasions, the IMI effort should yield a system that is sufficiently flexible that it can vary its level of interactivity as quickly as the occasion requires. The apparent requirement is to formulate an ES_4 that represents a quantum leap beyond capabilities of its ORE system alternatives. In light of many current imponderables concerning social organization, communications technology, and pedagogy of the future, we can expect that any current view of ES_4 eventually will be modified or supplanted. All that seems currently required is that ES_4 formulaters try to avoid the different forms of tunnel vision that various faiths promote.

Few doubt that there are many occasions where one would opt for individually managed instruction if it can be placed within applicable cost bounds for education. Nor do I doubt that in time we will be able to render such instruction on a productive basis referencing to total costs of education. However, some confuse the bird in the bush with the bird in the hand. A few comments on the status of the bird appear in order.

Models such as those described by Calfee (1969) and Atkinson (1972) suggest how the acquisition of items of a list of paired-associates might be made more efficient. Such models typically assume that a time-share computer serves as the instructional executive. Assuming that such models are compelling on acquisition efficiency grounds, it remains to make them equally compelling regarding system costs of instruction.

Extensive efforts addressing individually managed instructional systems that are sufficiently productive to merit installation have been underway in the educational research community for over a decade. Experience to date suggests that two factors yet hinder development of such cost-attractive systems. One is costs per student hour of instruction, which as yet exceed twice the costs of more conventional instruction. The other is that efficiency of individualized instruction, apart from hardware costs, as yet has been demonstrated only for a few sorts of instructional outcomes--most of these apparently falling in Gagne's verbal information learning domain. Any tendency of this paper to defer on development-installation of an IMI system does not, then, sacrifice a wonderous technology that, currently lying on the shelf, warrants immediate exploitation. Experience to date suggests that productivity of individualized instruction will depend to a degree on pupil proficiencies relative to national averages, teacher proficiencies, or both (cf, Jamison, Fletcher, Suppes, & Atkinson, 1971). Jamison et al. present data that support the view that essentially computer-delivered individualized instruction that is rationed to children at the rate of 10-15 minutes per student per day could be obtained by 1975 at a cost of $2 per student hour--somewhat over twice the cost of NEG system instruction. Only when such instruction is compensatory (i.e., when prior achievement levels are well below

national averages) will it enjoy a cost-benefit edge over instruction that is teacher-delivered in the NEG classroom. One should be encouraged rather than discouraged by such findings, since they represent progress in many useful senses--no minor one of which is cost-sensitivity. An effort that better focuses such research and associated hardware development over the next decade than it has been focused during the last decade should go far toward placing an IMI system in the advanced R&D domain.

A first line of inquiry for an IMI effort might determine, for the different learning domains and their subdomains, how frequently the system should interact with the student. Hopefully where individualized instruction is required, it will prove unnecessary to require the student to respond to every bit of instruction that is fed to him in the individualized situation or to predicate an instructional management decision on every response that the student makes. For there are cost gains to be had if it is found unnecessary ever, or on occasion, to descend to the level of mechanistic thoroughness that characterized the earlier efforts of programmed learning investigators.

A second line of inquiry for an IMI effort might determine, for the different learning domains and their subdomains, the form that supplemental instruction should take when initial instruction fails. The frequency of student-monitoring and of instructional management decisions determined, the problem is to say what to do about failures of initial instruction that are defined on the frequency framework. Findings on supplementation feed to engineering efforts of two sorts: a) development of supplementation-specifying tests and b) development of instructional programs that suitably differentiate initial instruction from a field of alternate forms of supplementation.

A decade hence, or soon thereafter, cable television will be available in school and home, communication between school and central computer via satellite will be possible, and, if we begin making the right efforts now, as Parker & Dunn (1972) advocate, terminal systems will be available that exploit cable television as an educational resource. Such terminals probably will need act in a quasi-independent manner throughout all or much of the instructional session or day, thus obviating the need to tie up a central computer on a continuing basis, a matter to which we will return. A third line of inquiry for an IMI system might be to postulate the multiply-sited educational system that an extension of Coleman's (1972) views implicates, to deduce how the different sites might be communications-netted in light of the multiple-site view and such technical developments as the Parker & Dunn project, and, in consequence, to reach views on the entire hardware requirement that, evaluated from a standpoint of minimizing procurement-operating costs, an IMI system that is a quantum leap forward will impose. For those who require imaginative action, the third line of inquiry should provide as much of it as any can handle.

An effort to achieve a developable IMI system probably will stress the automation of the more automatable facets of education. For we cannot appreciably individualize instruction on a cost-attractive basis unless some of the costs are transferred from personnel to machines. Experience suggests that an unacceptably inflexible system might result if the risk of rigidity that inheres in automation is not explicated and defensed against. No system--perhaps excepting NEG--can afford unlimited flexibility. Conversely, no system probably can afford to be rigid regarding instructional outcomes to be addressed and means to be employed. Educational objectives and means change more often than infrequently. It appears that a cost-attractive IMI system should be flexible both in a day-to-day sense--as a concession to the fact that at no point in life of the system can we expect it to be operating on the basis of an ultimate understanding of productive instruction--and in a longer-term sense--consonant with changing instructional mandates and advancing vistas.

The NEG system is too flexible in the day-to-day sense. It provides a flexibility that throws more decisions onto the teacher than applicable SOTAs warrant. NEG works well when provided with superb teachers and poorly otherwise. Superb teachers provided, NEG entertainably is productive and, if so, perhaps because it provides the teacher with the option of overcoming system deficiencies. It permits the teacher to address different instructional outcomes through quick rearrangment of the instructional situation--e.g., by moving furniture and shuffling paper. It provides "general purpose" equipment--e.g., projectors, tape cassettes, blackboards, typewriters, copiers, and paper--that the teacher may use to produce and present a wide range of supplemental materials. Moreover, although NEG floor plans tend to be inflexible, functional flexibility in cross-class organization is not precluded.

The problem with flexibility in the NEG system is that only an entrepreneur holding rare credentials can productively exploit it. An IMI system should retain some of this day-to-day flexibility, so that those personnel who are inclined to operate at or beyond knowledge horizons--the locus of professional effort--will not be shut out from doing so.

NEG's day-to-day flexibility and its longer-term flexibility have the same sources in NEG architecture. It should not prove too difficult to render the DPG, HPG, and HPG_2 systems day-to-day and longer-term flexible because, like NEG, they promise to be lean for specialized hardware. If individualization objectives of IMI can be met only by appreciably increasing the system's commitment to hardware that automates certain facets of instruction, then the task is to find hardware components that, while perhaps rather specialized at the component level, enter into alternative larger structures as readily as classroom furniture items do. For hardware structures that are readily reconfigurable to do different or new work consonant with day-to-day demands and longer-term changing requirements are probably the major portion of a flexible system.

Conventional computer-assisted instruction gives too prominent a role to a central remote large computer. Whether such a computer is tied to a field of instructional locuses by wires, telephone lines, or transmission channels, the system tends to secure a high level of computer-student interaction only by suffering large on-line costs. It is not yet compelling that an IMI system should have the single executive locus that conventional CAI tends to project. Alternatively, one may view an application of an IMI system as extending over appreciable geography, with a remote large computer exercising some executive functions, intervening minicomputers and associated devices exercising other, more local, executive functions, and instructional management executives and subordinates exercising still other executive functions at the locus of instruction. Moreover, it might make sense to specify a remote large computer able to do many things while subject to override on the part of instructional personnel as the occasion requires and to specify a field of minicomputer systems whose different members do different things that, together, provide a rich range of capabilities. Finally, it should be possible to reconfigure mini-computer systems quickly by patchboard to do different things and to yoke two or more systems or some of their components together, again by patchboard, to do other things. An IMI system so approached should be flexible enough to allow the true professional to operate in professional space lying beyond the frontiers of pedagogical science and to allow the system to respond to less than monumental changes in instructional mandates and elective options. It might also challenge those students who in time will come to resent an education that assumes that the son will learn only what the father knows and under conditions that the father can specify. Such a system might feature much gadgetry, but it would not be Ramo's machine shop, populated by metal masters who know no other guidance than the system designer furnished ten years earlier.

Synopsis of ORE Systems

The illustrative ORE systems all accept accountability requirements that the NEG system is able to escape. However, the different systems feature different modus operendi underlying accountability. The DPG system employs the failure-detecting test, whose effect is to burden the teacher with the problems of localizing failure and selecting apt supplementation. The HPG and HPG_2 systems employ failure-localizing tests that require the teacher only to select apt supplementation. The IMI system employs supplementation-specifying tests that maximally assist instructional personnel or assisting hardware to reach decisions that are appropriate to specified failures. As one mounts this scale of increasingly useful information, research and design-development-installation costs also mount. While it is too soon to conjecture concerning the rate at which such costs increase across the scale, the need for hardware probably increases in exponential fashion.

The DPG and HPG systems were formulated to be developable consonant with existing knowledge. It should be possible to develop these systems with only occasional minor recycling to an exploratory R&D domain. The HPG_2 and IMI systems were formulated to entail added exploratory R&D as a prelude to becoming developable. HPG_2 promises to be somewhat compatible with the prevailing educational architecture. However, IMI probably represents a radically changed architecture. We have begun to ask the right sorts of questions underlying the transfer of an HPG_2 system from the exploratory R&D domain to the advanced R&D domain. The effort, as sketched, might culminate in a developable system five years hence if R&D decision-makers would begin soon to push it toward that eventuality. Although I believe we should be giving serious attention to IMI now, it is not evident that the different scattered efforts on behalf of such a system are united under an umbrella of appropriate research-focusing questions. If greater efforts to frame these questions are not soon forthcoming, then too much of the earnest work now occurring on behalf of an IMI system promises to go down the drain reserved for those whose paramount concerns stem from a Buck Rogers ethic.

The illustrative systems scale for increasing individualization of instruction and for the form of supplementation that may occur when initial instruction fails. It is contended that increasing individualization of instruction, where needed, entails a decreasing extent of mandated instruction if the mandate is taken as universal and the same school day applies to everyone.

Table 1 compares the NEG system with the four ORE systems sketched above. With one exception, tabled ORE system values represent potential objectives for R&D efforts referencing to the different systems. The exception is the ratios presented for the contribution of personnel and hardware to instructional management and the processing-reporting of data underlying student-system evaluation. These ratios are conditional on other characteristics of the system. They are quite speculative. Their intent is to draw attention to the view that a counterargument that we are moving rapidly toward a Ramo machine shop which is unpopulated by instructional management executives and subordinate personnel is equally speculative at this point in our ability to evaluate such contentions.

The NEG system value for every factor shown in Table 1 is lower than the lowest value for that factor that an R&D effort will seek to achieve. There would be no point in an R&D effort that sought only to match an unacceptable NEG. The A code of Table 1 subsumes factors whose values foregoing remarks suggest should coincide for all ORE systems. The B code subsumes factors whose values should coincide for DPG-HPG and HPG_2-IMI pairs of ORE systems. The C code subsumes factors whose values should differ from one ORE system to the next. Covariation of factors subsumed under a code suggests that settings for some factors of a coded set might be constrained by settings for other factors in the set.

Table 1

A Comparison of the Existing NEG System with ORE Systems
Whose Characteristics Reflect R&D Objectives

Code and Factor	NEG System	ORE Systems			
		DPG	HPG	HPG_2	IMI
A1 GRADING	Norm-referenced	Outcome-referenced	Outcome-referenced	Outcome-referenced	Outcome-referenced
A2 ACCOUNTABILITY	Deferred and uncertain	Quick and certain	Quick and certain	Quick and certain	Quick and certain
B1 RELEVANCE	Domain mandates, traditional domains	Outcome mandates, traditional domains	Outcome mandates, traditional domains	Outcome mandates, relevant domains	Outcome mandates, relevant domains
B2 ELECTIVE OPTIONS	Restricted to high-rate students	Modestly available to all students	Modestly available to all students	Appreciably available to all students	Appreciably available to all students
C1 TEST INFORMATION	Quasi-failure-detecting at best	Failure-detecting	Failure-localizing	Improved failure-localizing	Supplementation-specifying
C2 TEST-BASED TEACHER ASSISTANCE	Minimal	Modestly above minimal	Low intermediate	High intermediate	Maximal
C3 SYSTEM-ORGANIZED INDIVIDUALIZATION	None	Little	Low intermediate	High intermediate	Maximal
C4 PERSONNEL-TO-HARDWARE WORK RATIO	99:1	97:3	95:5	90:10	50:50
C5 INSTRUCTIONAL PRODUCTIVITY	Low	Low intermediate	Intermediate	High intermediate	High

The instructional productivity factor of Table 1 reflects theoretical productivity of those instructional transits that the system requires or permits to be used. R&D objectives for ORE systems would be set higher if this could be done without our incurring an installation delay penalty for so doing. The productivity value for DPG assumes currently available knowledge; that for HPG, knowledge that will be available two years hence; that for HPG_2, knowledge that will be available five years or so hence; that for IMI, knowledge that will be available a decade or so hence. The tabled productivity values are posited cost-conditional, SOTA-optimized values, where SOTAs are closed as indicated above and costs are referenced to a posited installation time that is five years beyond initiation of an advanced R&D effort to develop the system.

The time at which the different ORE systems enter the advanced R&D domain appears influencable only to a limited extent in consequence of alternative decisions concerning what systems will be developed and what developed systems will be installed. We might gain a conventional CAI system that is cost-attractive but of less than general value much sooner than the envisioned IMI system. I regard systems like the conventional CAI system as partial systems, rather than total systems. The flexibility of NEG is such that we might want to develop and install partial systems as best we can into NEG as they become available and show value. That is done now, and with partial systems that, more often than not, are not required beforehand to show value. Our concern here is with total systems, rather than with partial systems that might be plugged into total systems to improve some special function of the total system. The illustrative total systems are so defined in terms of what new ground they must cover that it does not appear possible to appreciably accelerate their realization through the leapfrogging of less-ambitious systems. We are privileged to save some design-development-installation money through leapfrogging. However, the cost of these savings promises to be prolongation of NEG-level educational productivity and relevance. It is a myth that we could have an IMI system or something like it soon merely by turning on the Federal spigot. Properly aimed, that spigot is a necessary component to realization of such a system. However, no amount of money promises to make such a system available to society soon. The hard choices are concerned not just with "What?" but also with "When?" Although the illustrative ORE systems might be differently packaged to reflect different "What?" domains, "When?" still will remain a strict function of "What?"

IV

CONCLUDING NOTE

Heretofore, we have been concerned only with that portion of the student population we now find in the K-6 NEG school. Yet most of the comments on accountability and individualization--and particularly the former--are as apt to students now found in 7-9 and 10-12 NEG schools and to most prevailing college and university students, who for the most part also are the pawns of NEG education. Also, excepting for perfunctory remarks made in connection with the IMI system, we have not heretofore given consideration to the possibility that education in time will be multiply-sited in a formal sense.

There is a growing feeling that schooling at its best can only deal productively with a portion of the skills that are relevant to one's functioning as an effective young adult. Coleman (1972) views the intellective skills of schooling as important and perhaps even central to education. However, he views such skills as just one component of an extended education that, occurring across multiple sites in the community (e.g., school, hospital receiving room, factory instructional area, employment office), exhausts the many skills domains that are relevant to production of effectively functioning young adults. Given education so sited, it is likely that the movement of younger children across sites would be much less profound than that of older children. However, it might be useful, even when dealing with the students we now find in the K-6 NEG school, to begin thinking in terms of alternatives to the single schoolhouse.

Parker & Dunn (1972) note that cable television will reach the home--and so could reach any other site--to an appreciable extent by the early 1980s. They argue that the potential of this development for serving education will not be realized if we do not now begin considering the sorts of home terminal equipment that will be needed to exploit cable television for educational purposes. It appears that such equipment should have something in common with the terminals that IMI requires. One could, of course, assume that the home will supplant the school as the locus of academic education on entry of cable television as a near-universal characteristic of homes. A more likely possibility is that home instruction via cable television will only supplement schooling in the shorter-term longer term. Home-sited instruction might be particularly suited to addressing the elective options of younger children.

Although home-sited instruction, particularly regarding mandated outcomes, assumes levels of maturity we cannot expect to find in most younger children, at some point most students should reach appropriate maturity. Cable television well may represent the technical breakthrough we need to promote extensive continuing education

of adults. Continuing education is old in concept and modest in practice. If Brzezinski (1970) is correct, then a) the workforce by the early 1980s will be appreciably in occupations that are knowledge system-exploitative, b) there will be a staggering technical compulsion to upgrade skills within occupations on a periodic basis, and c) there will be a compelling psychological basis for changing occupations after 15-20 years of doing a given thing. If the demand for college-level continuing education expands in consonance with Brzezinski's views, then we will require a cable television capability for providing education in the home just as quickly as this capability can be obtained.

As one reaches beyond the K-6 schoolhouse, it is inevitable that one will encounter new challenges. However, it is less likely that educational systems will need to be reformulated in light of these challenges than that these systems will need to be extended to accommodate the challenges. I would as quickly entertain moving the prevailing university system into the DPG-HPG era as moving the prevailing K-6 system. The principal difference between the two undertakings is a difference between freeing big pawns and little ones.

TECHNICAL APPENDIX

Relevance insured, the paramount function of an educational system is to secure system criterion performance. An extended effort is required to obtain definitively stable performance standards for the system. This effort becomes increasingly complex with increasing individualization of instruction because the standards for a highly individualized system should hold the system equally accountable for optimizing transit times for students manifesting every rate predisposition. This problem is minimized but not eliminated for a DPG system. Such a system will feature a minimal standard with regard to rate through mandated instruction and a maximal standard. In light of the teacher's limited options for differentially transiting students through instruction, the distribution of rates falling between minimal and maximal rates would be a crude one. Perhaps the ultimate level of cross-class sophistication we might aspire to when DPG system performance is to be evaluated is one that indicates the proportion of students who should be transited at the minimal rate, the proportion who should be transited at the maximal rate, and, by subtraction, the proportion who should be transited at an intermediate rate. For present illustrative purposes, we will ignore the complicating cross-class characteristics of standards. The standard setting activity will be described for a DPG system, for the most part in terms of a minimal transiting rate requirement.

The effort to obtain definitively stable performance standards for the system begins early in system design-development and reaches completion only after the installed system has operated for the duration of its programmed instructional transit time. When transit time is on the order of that for K-6 instruction, the effort to produce definitive standards may last for over a decade. Hence, interim standards are required. The envisioned DPG system features a progression of interim standards culminating on a definitive standard.

Optimization of mandated instruction for relevance yields $m \times n$ instructional outcome sequences. If we assume a square matrix of these sequences, then the notion that mandated instruction addresses six skills domains for seven years signifies occurrence of 42 such sequences. Each outcome in such a sequence is a specification that the student negotiate a certain test item or problem domain. Outcome specification should indicate a) that responses to some of these items will be selected (or cued)--e.g., to evaluate proficiency for recognition (or identification) of associative patterns or concepts, b) that responses to other items will be constructed using alphanumeric or other elements, where these elements sometimes will and sometimes will not be made available to the respondent, c) that responses to still other items will be constructed to evaluate recall (with or without major motor accompaniment) of associative patterns, concepts, and algorithms, and finally d) that responses to some items will stress psychomotor skill. The envisioned DPG system assumes system specifications that explicitly

address response form requirements--which prevailing education at all levels too often treats as a matter of taste. Instruction cannot be relevant that teaches inapt response forms.

Experientially-based intuition can be used to partition each of a system's mandated outcome sequences into segments, with each segment defining a unit failure-detecting test (FDT) that unit instruction will address. For a given skills domain, the test sequence specifies a set of unit FDT performances that the system will be required to cause the student to achieve. However, the test sequence does not specify the instructional transit time that will be allowed the system to reach specified performance.

A test sequence is a preliminarily chunked outcome sequence. System standards for criterion performance, CPs, result when test sequences for the different skills domains are calibrated to instructional transit time. The calibrated test sequences, or CPs, are appreciably empirically determined. However, if calibration conditions are fully consonant with system specifications, then obtained CPs must be strict consequences of the designed-developed system's productivity. Since system specifications characterize students entering every level of the system's n-year sequence as graduates of all prior levels of the sequence, only the definitively stable CPs that can be gauged after the system has operated for n years can be fully consonant with system specifications. Hence, there is a need for interim CPs.

Experientially-based intuition is used to effect preliminary "calibration" of each test sequence. Earliest design-development efforts require operation of such a guesstimation process, which preliminarily establishes instructional coverage during specified transit time. These guesstimates stem from hunches concerning power of applicable SOTAs to raise productivity of prevailing instruction. They are denoted CPAs. The A of this notation signifies that the CP to which it is attached is a first-pass standard based on guesstimation.

During tryouts, the system at best is operating at a lower bound for productivity. Moreover, tryouts at all levels higher than first-year accept entering students who are graduates of prior NEG instruction, rather than of contemplated prior DPG instruction. These tryouts effect provisional calibration of test sequences. The tryouts yield provisionally calibrated unit FDTs that are denoted CPBs. CPBs must understate the standards for criterion proficiency that we must eventually require the system to meet because the tryout system at best is prototypic and students entering instruction at progressively higher levels are decreasingly appropriately entry proficient.

Development tryouts cannot establish the definitive values that CPs should assume because the installed system will prove more than prototypic. In consequence, CPB values probably should be elevated to reflect the productivity edge that the installed system enjoys over

prototypic tryout systems. Hunches concerning the power edge of the installed system are applied to effect adjusted provisional calibration of test sequences. The result is adjusted provisionally calibrated unit FDTs that are denoted CPCs. There exists at this point an m x n set of CPCs addressing mandated instruction. Each CPC consists of 10-12 FDTs--one per instructional unit for a given skills domain at a given year level.

Achieved performance of the system during its first year of operation is denoted Set CPC. System specifications require that Set CPC = Set CPC--that is, that achieved performance for each skills domain at each year level correspond to that specified by a standard for system performance for domain and year.

A CPC is equally apt to evaluation of individual student proficiency and system performance. However, if we require students to exit from given mandated instruction with the same mandated proficiencies, then it is likely that students in a given class will require somewhat different transit times to complete an instructional unit or year in a specified skills domain. Hence, the system will accept student dispersion referencing to mandated instruction only for transit time. Allotted transit time to complete a unit or year--or to reach mandated proficiency levels for the unit or year--is a maximum value (reflecting a minimal standard). Dispersion of student transit time will occur below that value. Students who attain unit proficiencies ahead of allotted instructional time then move to optional elective instruction.

The operating system having an n-year transit may be installed either longitudinally or simultaneously. Longitudinal installation contemplates installation only of first-year instruction during the system's first year of operation, with installation of each succeeding year of instruction occurring during each succeeding year of operation. In longitudinal installation, students entering every year level of the n-year transit are graduates of the system's prior instruction. Simultaneous installation contemplates installation of all year levels of the n-year transit during the system's first year of operation. Only after the system has operated for n-1 years will graduates of prior instruction at all year levels have received only DPG instruction. The CPCs that are appropriate to the two forms of installation are not identical standards.

The CPCs appropriate to both types of installation reflect upward adjustment of CPBs to compensate for the prototypic character of the tryout system in which CPBs are obtained. However, longitudinal installation requires only a first-year standard during the first year of system operation. This standard is CPC-1. Simultaneous installation requires a full set of standards during the first year of system operation--CPC-1, CPC-2(1), . . . , CPC-n(1). The CPC-1 values used during the first year of operation reference to contemplated entry proficiencies. Hence, CPC-1 values are estimates of definitive standards for first-year instruction. After one year of operation, the estimate CPC-1 gives way to CPN-1, a first-year definitive standard.

Longitudinal installation does not require that the estimate CPC-2 be made prior to the outset of the second year of operation, CPC-3 prior to the outset of the third year, or CPC-n prior to the outset of the nth year. These estimates, when made, will compensate both for the prototypic character of the tryout system and for the fact that entering students at higher levels are graduates of DPG, rather than NEG, instruction. After completion of a second year of operation, the estimate CPC-2 should give way to the definitive standard CPN-2. After completion of an nth year of operation, the estimate CPC-n should give way to the definitive standard CPN-n. Thereafter, system performance will be acceptable if Set CPN = Set CPN.

When installation is simultaneous, entering students at higher levels are graduates of prior NEG instruction rather than prior DPG instruction. Hence, adjustment of CPBs to CPCs at higher levels for purposes of a first year of operation will yield higher-level values that are lower values than the corresponding higher-level values for longitudinal installation. These values, CPC-2(1) through CPC-n(1), will compensate for inappropriateness of prior instruction. CPC-2(1) should give way to the estimate of a definitive second-year standard, CPC-2, during the system's second year of operation; CPC-2 should give way to the definitive second-year standard after completion of the second year of operation. CPC-n(1) should give way to CPC-n(2) during the second year of operation, to CPC-n(3) during the third year, etc. Finally, CPC-n(n-1) should give way to the estimate of a definitive nth year standard, CPC-n, during the system's nth year of operation. Thereafter the setting of standards for simultaneous installation will be identical with the setting of standards for longitudinal installation.*

The R&D effort relating to the setting of definitive standards cannot be completed until the new system has been operating for n years. It begins during system design-development with CPA guesstimations. These give way to CPB values that are empirically determined under tryout conditions. CPB values in turn are adjusted upward to CPC values to

---

*A technical problem requiring resolution is how to isolate the activities of setting, adjusting, and evaluating criterion performance standards from tendencies of the prototypic or installed system to perform at subcriterion levels. Suffice to say that two possibilities are discernable. During tryouts, subcriterion performance could be minimized by maximizing the R&D role in operating the system. During operation of the installed system in a population of classrooms, activities bearing on definition of standards might take performance of the more-productive classrooms--e.g., those whose progress falls in the top one or two quartiles--as indicative of criterion performance. Such data would be baseline referenced to entry proficiencies. Hence, measures of classroom productivity would not be confounded with differences in entry proficiency from class to class.

compensate for the superiority of the installed system to the tryout system. The initial CPC values of longitudinal installation and terminal CPC values of simultaneous installation are estimates of definitively stable standards. These definitive standards, CPN values, are empirically determined under appropriate operating conditions for the installed system.

The effort fairly to evaluate system performance against standards for accountability poses a wider range of problems than have been touched upon above. Perhaps that is why some opt to bypass the accountability question by tossing it into the lap of a voucher-armed parent while others attempt to do somewhat the same thing by conjuring up a machine shop education that is devoid of human frailty. One can only say to those who see the difficulty but not the way out that reform beyond the painless level of rhetoric is bound to require a certain amount of effort.

REFERENCES

Atkinson, R.C. Ingredients for a Theory of Instruction. Technical Report No. 187, 1972, Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, California.

Bane, M.J. & Jencks, C. The Schools and Equal Opportunity. Saturday Review, September 16, 1972, 37-42.

Bereiter, C. Schools without Education. Harvard Educational Review, 1972, 42, 390-413.

Bloom, B.S. (Ed.) Taxonomy of Educational Objectives. New York: Longmans, Green, 1956.

Brzezinski, Z. Between Two Ages. New York: Viking Press, 1970.

Calfee, R.C. The Role of Mathematical Models in Optimizing Instruction. Theoretical Paper No. 17, 1969, Wisconsin R&D Center for Cognitive Learning, University of Wisconsin, Madison, Wisconsin.

Coleman, J.S. How do the young become adults? Phi Delta Kappan, 1972, 54, 226-230.

Ellul, Jacques. The Political Illusion. Translated by Konrad Kellen. New York: Knopf, 1967.

Ellul, Jacques. Autopsy of Revolution. Translated by Patricia Wolf. New York: Knopf, 1971.

Gagné, R.M. Domains of Learning. Interchange, 1972, 3, 1-8.

Glaser, R. & Resnick, L.B. Instructional Psychology. Annual Review of Psychology, 1972, 23, 207-276.

Jamison, D., Fletcher, J.D., Suppes, P., & Atkinson, R. Cost and Performance of Computer-Assisted Instruction for Education of Disadvantaged Children. Technical Report No. 175, 1971, Stanford University, Stanford, California.

Kriewall, T.E. Applications of Information Theory and Acceptance Sampling Principles to the Management of Mathematics Instruction. Technical Report No. 103, 1969, Wisconsin R&D Center for Cognitive Learning, University of Wisconsin, Madison, Wisconsin.

Parker, E.B. & Dunn, D.A. Information Technology: Its Social Potential. Science, 1972, 176, 1392-1399.

Scriven, M. The Methodology of Evaluation. In R.W. Tyler, R.M. Gagne, & M. Scriven. Perspectives of Curriculum Evaluation. Chicago: Rand McNally, 1967. Pp. 39-83.

Siegel, L. & Siegel, L.C. A Multivariate Paradigm for Educational Research. Psychological Bulletin, 1967, 68, 306-326.

Stephens, J.M. The Process of Schooling. New York: Holt, Rinehart & Winston, 1967.